



NASA ARMSTRONG STATE OF DISCIPLINE

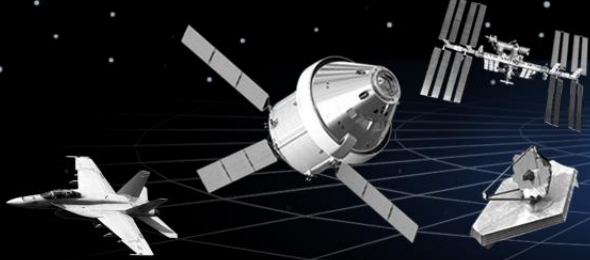
May 9-11, 2023

NESC Loads & Dynamics (L&D) Technical Discipline Team (TDT) Face-To-Face (F2F) Annual Meeting
NASA Michoud Assembly Facility (MAF) near Stennis (SSC), New Orleans, LA

Natalie Spivey, Keerti Bhamidipati & Dr. Chan-gi Pak
Structural Dynamics Group
NASA Armstrong Flight Research Center

ARMSTRONG

Center POC: Natalie Spivey, Keerti Bhamidipati & Dr. Chan-gi Pak



L&D Support Overview

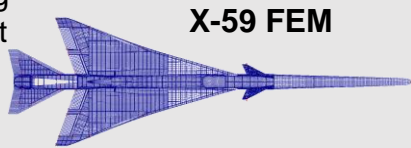
- AFRC’s Overview Statement
 - AFRC is NASA’s primary center for high-risk, atmospheric flight research and ground testing on modified or unique research vehicles and test articles
- AFRC’s L&D Facility
 - Flight Loads Lab (FLL): High-bay test area with flight line access for large-scale structural & thermal testing of aerospace structures for component and airframe qualification/airworthiness & research
- AFRC’s L&D Expertise
 - Mainly supports projects in the Aeronautics Research Mission
 - Aeroelasticity, Model Tuning, FEM & Flutter Analysis Airworthiness Clearance support
 - Modal Testing, Mass Property Testing & Flight Testing

Challenges/Concerns

- Loss of institutional knowledge and experience through attrition; takes several years to fully train in aeroelasticity & flight testing
- Industry competition & AFRC’s desert/desolate environment makes hiring experienced people difficult; reduction of Center FTE #
- Staffing challenge with engineers fractioned between multiple projects
- Mentoring challenge with people working multiple projects & NASA Future of Work (telework/remote)
- Keeping staff trained and competent with GVT & FEM software / tools
- Lack of research funding to developed new measurement techniques for flight testing prior to project execution

Accomplishments

- Supporting X-59 Low-Boom Flight Demonstration (LBFD) aeroelastic efforts
 - GVT TRR (8/22) & SCT TRR (1/23) & planning
 - FEM tuning & shape sensing tool development
 - Control room display development
 - Flight test planning
- Supporting X-57, NASA All-Electric X-Plane
 - Mod II & III flutter analyses and flight test planning
 - Mod II electric motor troubleshooting, motor vibration environment measurements, & component vbe testing
- Supported F-18B + wing pod airworthiness clearance
- Supporting various F-15B/D Flight Experiments
- Slam Stick work for multiple projects
- GVT of AATT’s Mock Transonic Truss-Braced Wing (TTBW)



X-59 FEM



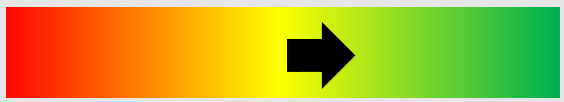
X-57 Mod II

Discipline Health



Y+

Work



Y+

Workforce



G-

Workplace

L&D Support Overview

ARMSTRONG



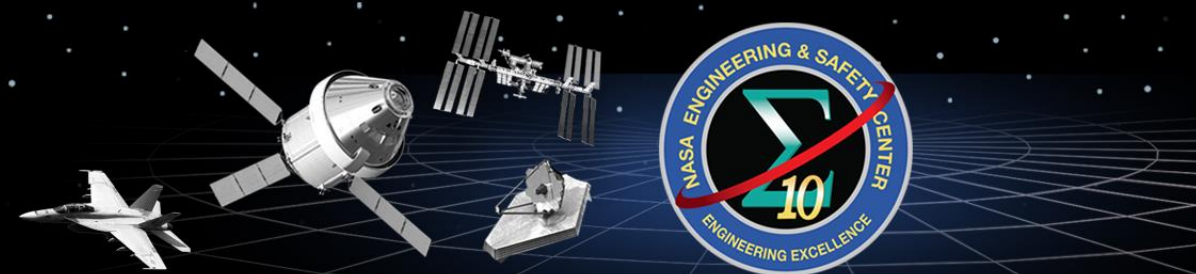
- Armstrong's Overview
 - AFRC's Aerostructures Branch (560) supporting L&D
 - Testing capabilities:
 - Ground testing – Modal, ASE, Freeplay & Mass Property
 - Flight testing – Envelope Clearance & Flutter
 - Analysis capabilities:
 - Aeroelastic & Aeroservoelastic Modeling & Analyses
 - FEM Development and tuning using test data
 - Modal Analysis
 - Shape sensing using strain data
 - Optimum shaker and accelerometer placement tool
- Major programs: X-57, X-59, F-18B + Wing Pod, various F-15B/D Flight Experiments (SSP, Flow Rake, CATNLF), Slam Stick work for multiple projects, Mock Advanced Air Transport Technology (AATT) Truss-Braced Wing
- L&D TDT Members from Armstrong
 - Natalie Spivey, Structural Dynamics Testing SME (6-yrs)
 - Keerti Bhamidipati, Structural Dynamics (2-yrs)
 - Dr. Chan-gi Pak; Structural Dynamics Analysis SME (1-yr)

Armstrong's Flight Loads Lab (FLL) – High Bay



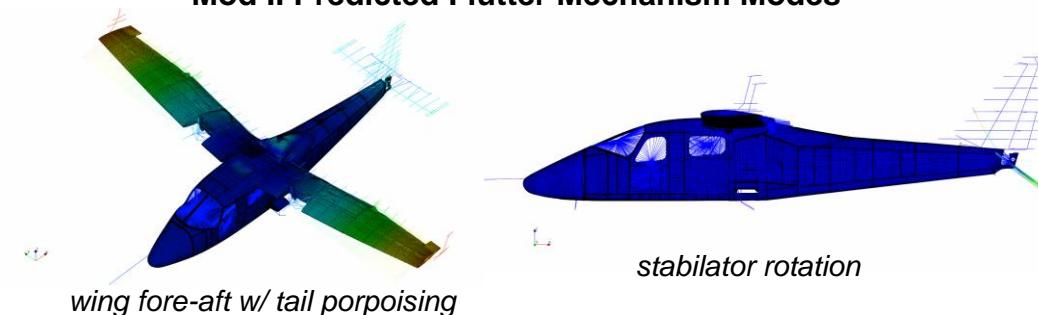
Accomplishments

ARMSTRONG

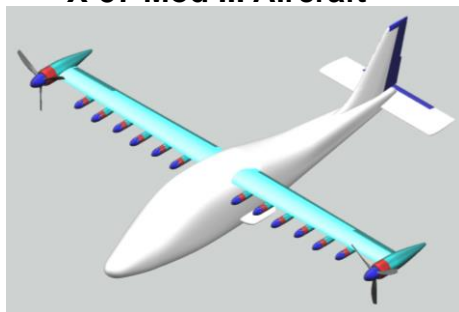


- Supporting X-57, NASA's All-Electric X-Plane
 - Mod II Airworthiness Clearance
 - Supported aircraft ground motor runs, cruise motor vibration environment measurements, and component vibration testing
 - Classical Flutter analysis & Whirl Flutter assessment
 - Flight Test Planning, 1st flight TBD
 - Mod III classical and whirl flutter analysis to support wing fabrication

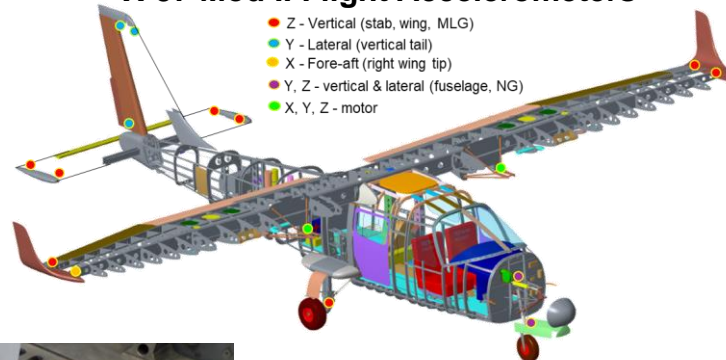
Mod II Predicted Flutter Mechanism Modes



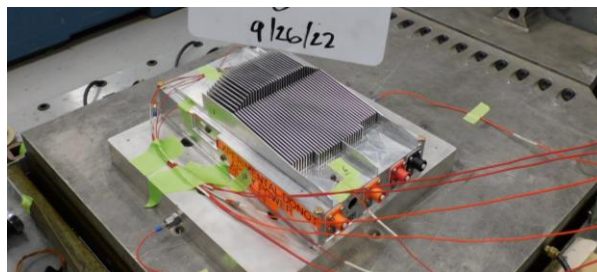
X-57 Mod III Aircraft



X-57 Mod II Flight Accelerometers



Mod II Ground Motor Runs and System Integration Tests



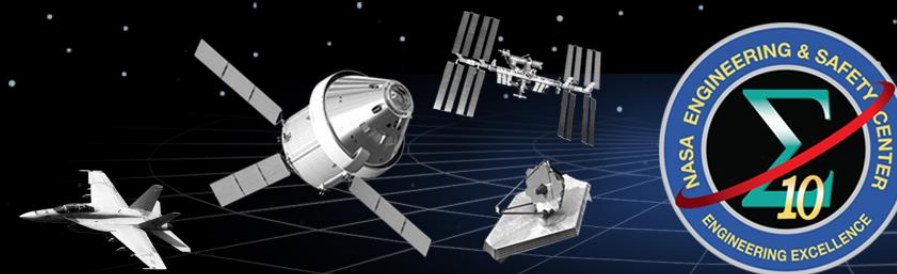
CMC
Vibration
Testing

Cruise Motor Vibration Measurements



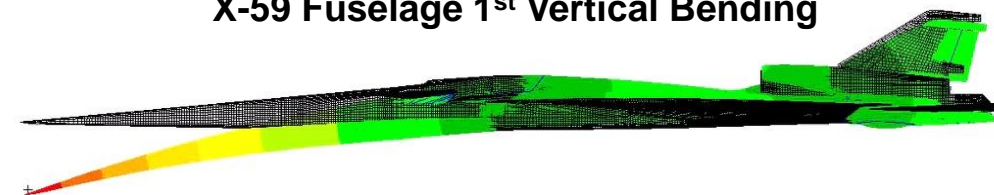
Accomplishments

ARMSTRONG



- Supporting X-59, Low-Boom Flight Demonstration (LBFD) Aeroelastic Efforts:
 - FEM analysis
 - Flutter analysis
 - Aeroservoelastic (ASE) Analysis
 - Preparing for FEM correlation and tuning
 - Developed shape sensing and FE model tuning tools
 - Ground Vibration Test (GVT) TRR (8/22) & Planning
 - Structural Coupling Test (SCT) TRR (1/23) & Planning
 - Control room display development
 - Flight test planning

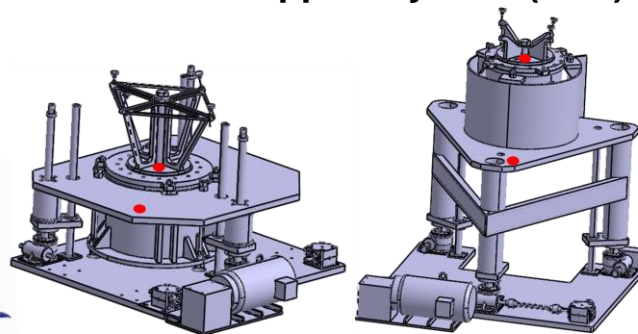
X-59 Fuselage 1st Vertical Bending



X-59 Construction



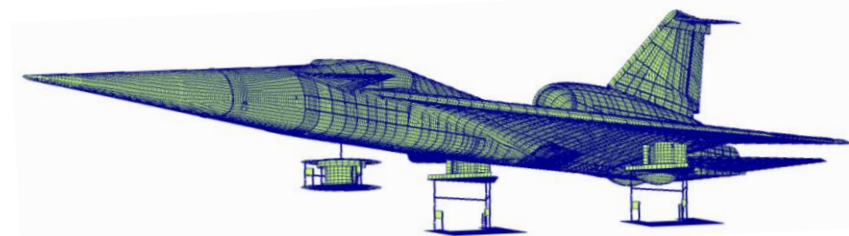
X-59 Soft Support System (SSS)



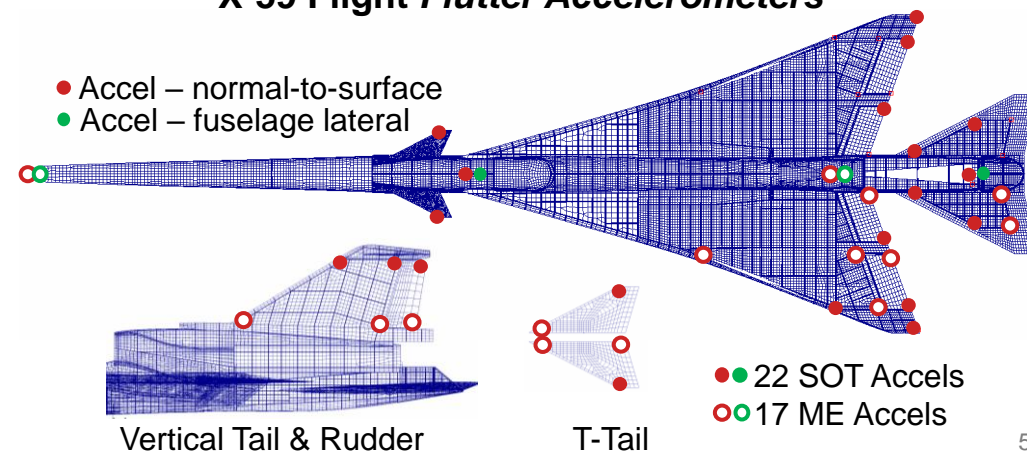
Fwd SSS

Rear SSS (2x)

X-59 FEM on Soft Supports for GVT & SCT

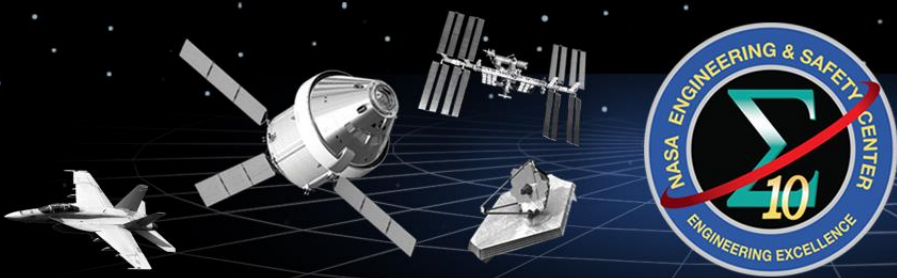


X-59 Flight *Flutter* Accelerometers



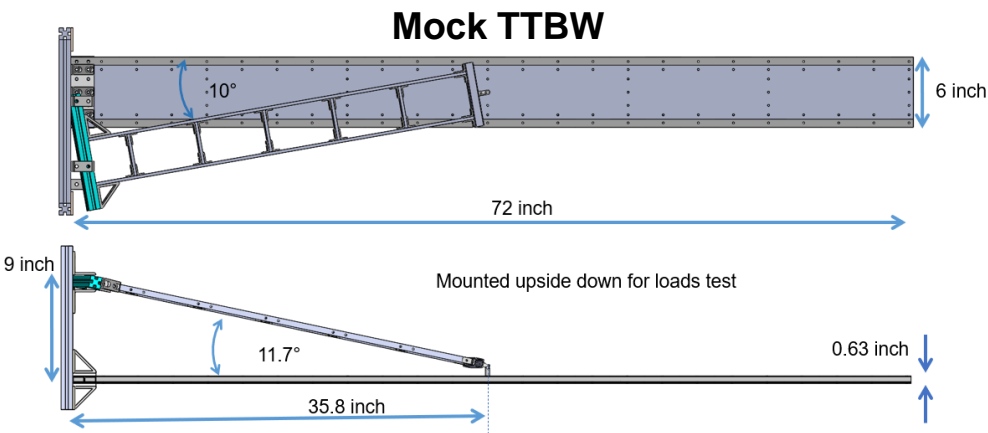
Accomplishments

ARMSTRONG



- Supporting Advanced Air Transport Technology (AATT) Mock Transonic Truss-Braced Wing (TTBW)
 - Developed & built a proof-of-concept of the TTBW to investigate strut connection & affects on wing
 - Created FEM
 - Performed modal analysis
 - GVT attached to FLL Strongback
 - Unloaded & Loaded configurations
- NASA awarded Boeing's Transonic Truss-Based Wing for Sustainable Flight Demonstrator (SFD) project in Jan. 23

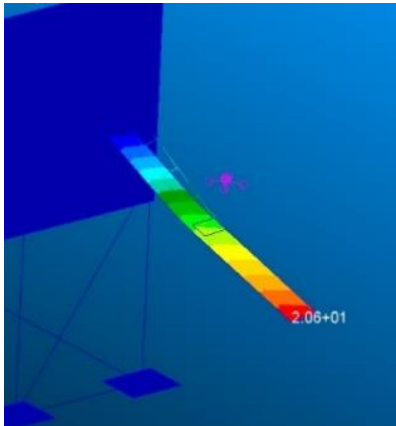
Boeing's Transonic Truss-Braced Wing (TTBW) Configuration



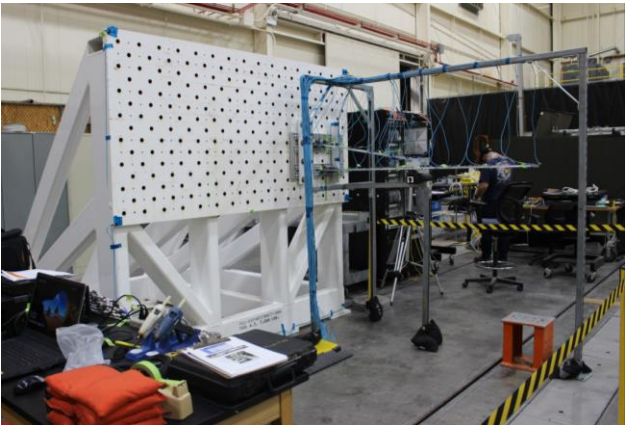
Mock TTBW Design

Parameter	Value
Half Span	72 in
AR	12
Truss Sweep	10°
Truss Dihedral	11.7°

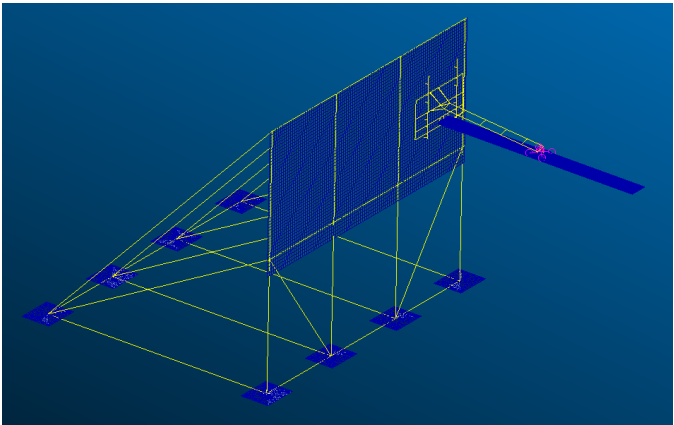
Wing 1st Bending with Sym Truss Bending



Mock TTBW GVT Setup

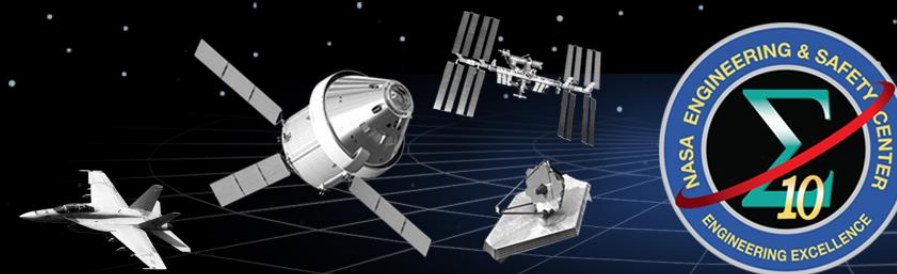


Mock TTBW + Strongback FEM



Challenges/Concerns

ARMSTRONG



• Challenges

- Loss of institutional knowledge and experience through attrition; takes several years to fully train in aeroelasticity & flight testing
- Industry competition & AFRC's desert/desolate environment makes hiring experienced people difficult
 - Reduction of Center FTE #
 - Agency's shift to Term positions vs. Permanent positions
- Staffing challenge with engineers fractioned between multiple projects
- Mentoring challenge with people working multiple projects & NASA Future of Work (telework/remote)
- Keeping staff trained and competent with GVT & FEM software / tools
- Lack of research funding to develop new measurement techniques for flight testing prior to project execution

• Actions taken

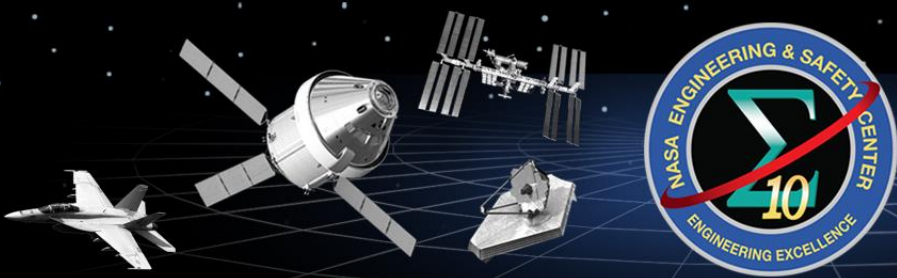
- Better internal branch documentation & file storage which helps locate older institutional discipline documentation
- Recently (within 18 months) hired two new structural dynamics employees
 - Developed detailed outline for first 6-months & held bi-weekly mentoring meetings
- Employee training when opportunities arise

Workforce Feedback

- Endangered Skills at AFRC (top 3)
 - Aeroservoelasticity
 - Aeroelastic Analytical
 - Aeroelastic Testing
- L&D Attrition at AFRC
 - Small structural dynamics group (7 people currently)
 - Last 5 years: lost 6 people & only hired 3 people with little or no aeroelasticity experience
 - Lost 2 Senior aeroelasticity engineers (≈ 35 & 40 yrs) to retirement
 - Will lose 2 additional senior engineers in ≈ 2 -3 years
 - Lost 3 Mid-career level ($\approx 10, 12$ & 15 yrs) to other NASA career tracks or left NASA
 - Lost 1 Early-career (≈ 2 yrs) left NASA

Discipline Health

ARMSTRONG



Y+

Work

- AFRC dynamics had adequate work with two X-planes & other flight research
 - X-57 is struggling & X-59 is behind schedule
 - Sustainable Flight Demonstrator (SFD) awarded to Boeing in early 2023 will bring lots of future work



Y+

Workforce

- Several experienced employees have left the discipline for various reasons
- Upcoming senior retirements
- Recent new hires (early career) & takes time to get up to speed
- Knowledge transfer / mentoring difficulties



Y

Workforce Discipline

- AFRC has an Aeroelastic Analytical & Testing subject matter experts (SME)



Y

Workplace Resources

- GVT software & FEM tools training continues, working sensor replacements



G-

Workplace Facilities

- AFRC's FLL is doing well, but nearly 60 years old; Facility & unique test systems aging/degrading. High repair/sustainment costs; Electrical & fire suppression systems need replacement ~ \$10 Million